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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Provides a method of evaluating projectiles for structural strength and terminal effects. Applicable to nonnuclear projectiles for field and air defense artillery, tank guns, mortars, and recoilless rifles.

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Incl 2

US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-103
*Test Operations Procedure 4-2-501 1 April 1979
AD No.

PROJECTILES

1. SCOPE. This TOP describes procedures for testing developmental and production projectiles for structural strength and terminal effects. It covers nonnuclear projectiles for field and air defense artillery, tank guns, mortars, and recoilless rifles. (For complete round evaluation see TOP 4-2-011, Artillery Ammunition; 4-2-012, Mortar Ammunition; or 4-2-013, Ammunition, Recoilless Rifle. For safety evaluation, see TOP 4-2-504.)

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENTS
Firing ranges and recovery field	Selected from the facilities listed in DARCOM-P 70-1 1/ to suit test requirements
Temperature	Range of -51.1° C (-60° F) to +62.8° C (+145° F)
Rotating band testing machine	As described in TOP/MTP 4-2-803
Fragmentation test arena	As described in TOP/MTP 4-2-813
Targets	(1) Accuracy and dispersion test as described in TOP 4-2-829

*This TOP supersedes TOP 4-2-501, 11 May 78 including all changes.

1/ DARCOM-P 70-1, DARCOM Test Facilities Register, May 1976.

ITEM	REQUIREMENTS
	(2) Armor plate of the type and thickness stipulated by test specification
Photographic facilities	Camera, 35-mm, smear-type (TOP/MTP 4-2-815), to record metal parts breakup
	Camera, 35-mm, framing, 1 to 5000 frames/sec, to record smoke, sabot discard, and other projectile performance elements

2.2 Instrumentation.

ITEM	MAXIMUM ERROR OF MEASUREMENT*
Projectile velocity measuring equipment (TOP 4-2-805)	Velocity to 3,048 m/s (10,000 fps) ±0.1%
Weapon pressure sensing equipment (TOP 3-2-810)	Pressure to 689,480 kPa (100,000 psi) ±2%
Rate of spin measuring equipment (TOP 4-2-811)	Spin rate (rps) ±2%
Meteorological equipment:	
Windspeed	0 to 44.7 m/s ±0.8 m/s (0 to 100 mph ±1-3/4 mph)
Wind direction	360° ±3°
Temperature	-35° to +50° C ±0.2° C
Relative humidity	5% to 100% RH ±2%

*Values may be assumed to represent ±2 standard deviations; thus the stated tolerances should not be exceeded in more than 1 measurement out of 20.

3. PREPARATION FOR TEST.

3.1 Planning.

a. Prepare a test operations checklist using appendix A as a guide and adding specifics for the test item and situation.

b. Design data collection sheets for recording round-by-round data as required by the particular test.

3.2 Weapon. Select a weapon for which the projectile is standard and which has at least 75 percent of its service life remaining, unless otherwise specified in the requirements documents for the projectile being tested.

3.3 Ammunition.

a. Make prefiring physical measurements of the projectile as described in TOP/MTP 4-2-800.

b. Assemble projectiles used as fixed or semifixed ammunition into complete rounds using components from acceptable stock lots. Use inert-loaded or live projectiles and the propelling charge (service or adjusted) as indicated for the particular test. (For description and use of inert fillers see appendix B.) When internal pressure gages (TOP 3-2-810) are used, place the gages in the cartidge case before loading. Crimp cartridge cases of fixed ammunition to the projectiles in accordance with the applicable ammunition specification to give the required bullet pull.

c. Measure the diametrical clearance between rotating bands and bandseats in accordance with TOP/MTP 4-2-803.

3.4 Instrumentation.

a. Position a smear camera (TOP/MTP 4-2-816) forward of the weapon muzzle to photograph metal parts separation during the initial flight of the projectile. The intercept point of the trajectory should be at a distance from the muzzle that will prevent image obscuration by smoke. In addition to photographic coverage, the doppler velocimeter may be used to detect metal parts separation. The application of this instrumentation is described in TOP/MTP 4-1-005.

b. Install instrumentation to measure the following in accordance with the listed reference:

(1) Muzzle velocity as described in TOP 4-2-805.

(2) Weapon chamber pressure as described in TOP 3-2-810.

(3) Meteorological data as described in TOP/MTP 3-1-003.

4. TEST CONTROLS.

a. Record standard surface and upper-air meteorological data (TOP/MTP 3-1-003) immediately before firing starts and at least hourly while firing is in progress. When the maximum ordinate is below 300 meters, record only surface data.

b. Unless otherwise specified, condition ammunition and internal pressure gages to $+21.1^{\circ}$ C ($+70^{\circ}$F) for a minimum of 24 hours before firing or until stabilized at that temperature.

c. Inspect the weapon throughout testing in accordance with the schedules of TOP 3-2-800 or more frequently when there are unexpected occurrences such as projectile breakup, cartridge case rupture, chamber pressures in excess of 110 percent of the Permissible Individual Maximum Pressure (PIMP), during a firing program.

d. Use a propelling charge that has been developed and tested to meet the safety test pressure requirements. It may be necessary to add propellant to a standard charge or develop a special proof charge to achieve the desired pressure levels. Caution: If weight adjustment is required to adjust the desired pressures, coordinate with an interior ballistics specialist to insure that there will be no damage to the weapon

5. PERFORMANCE OF TESTS

5.1 Strength of Design. Perform the following test to verify that the projectile can successfully withstand the maximum forces of weapon launch.

5.1.1 Method.

a. Fire a group of 10 rounds assembled with inert-loading projectiles and with the propelling charge adjusted to 5 percent above weapon or projectile PIMP as defined in TOP 4-2-504. Observe the rounds fired to determine whether the projectiles reach the expected impact area. Recover each projectile using a technique selected from those described in TOP 4-2-809.

b. During firing, photograph the initial flight of each projectile and measure chamber pressure (TOP 3-2-810) and muzzle velocity (TOP 4-2-805) for all rounds. For those projectiles whose design permits variation in spin rate, periodically measure the projectile rate of spin as described in TOP 4-2-811.

c. Record range and deflection data for recovery purposes if the rounds are not fired into a recovery box.

d. After recovery, remeasure the projectile for dimensional changes as described in TOP/MTP 4-2-800.

e. Examine the recovered projectile for the following as applicable:

(1) Loss or breakup of metal parts components.

(2) Excessive looseness of the rotating band. Slipping or humping of rotating bands should not exceed specified tolerances.

(3) Evidence that the rotating band imparted spin to the projectile. (When fired from a new weapon, the rotating band should take a reasonably accurate impression of the weapon rifling. There should be no evidence of slippage of the band on the band seat. When fired from a worn weapon, the rotating band will not take a clean impression of the

rifling. This lack of a clean impression is called "shearing" and is normal for a worn weapon. A recovered rotating band that is smooth, with no impression, may indicate that the weapon life has been exceeded or that the band design is inadequate, depending upon the life requirements of the system.)

(4) Evidence of filler leakage around joints of multipiece projectiles or movement of components with respect to one another.

(5) Rifling marks around the entire circumference of the recovered projectile body for evidence of upsetting; i.e., failure of cylindrical body in radial expansion caused by axial compression.

f. Certain projectiles such as high velocity, kinetic engergy, armor piercing projectiles, may not lend themselves to recovery as described in TOP 4-2-809. In these cases, the evaluation of strength of design must rely on data obtained from cameras, flash radiography, and radar. In the case of saboted, high velocity projectiles, it is often possible to recover parasitic hardware by thoroughly searching large areas forward of the weapon. Recovery of such parasitic hardware is often of extreme value in diagnosing the causes of metal parts failure during launch.

5.1.2 Data Required.

a. Projectile identification.

b. Complete round component identification.

c. Propelling charge weight.

d. Projectile physical measurements before and after firing as described in TOP/MTP 4-2-800.

e. Weapon identification.

f. Recovery method.

g. Firing elevation.

h. Firing data as specified in 5.1.1b above.

i. Results of examinations specified in 5.1.1e.

j. Meteorological data.

5.2 Terminal Effects. Determine projectile terminal effects using the procedures and subtests described below as applicable to the projectile being tested.

5.2.1 High Explosive Projectiles.

5.2.1.1 Method.

a. Conduct accuracy and dispersion tests as described in TOP 4-2-829 for direct fire weapons or as described in TOP/MTP 3-1-004 for indirect fire weapons.

b. Conduct static fragmentation tests as described in TOP/MTP 4-2-813.

c. Compute projectile lethality from the data collected in a and b above using the procedures of TOP/MTP 3-2-608.

d. Determine projectile functioning characteristics and a preliminary estimate of reliability by firing the projectile with each of its various fuze types (impact, time, and proximity) for a minimum of 10 rounds per fuze type at 21.1° C (70° F) and, unless otherwise specified, at -51.1° C (-60° F) and +62.8° C (+145° F). Fire in accordance with paragraph 5.1.1a above. Functional firings may be conducted simultaneously with the accuracy and dispersion tests and range firing tests.

e. Determine order of functioning using the criteria of TOP/MTP 4-1-003.

5.2.1.2 Data Required. Record test data as indicated by the specific procedures above.

5.2.2 Chemical Projectiles.

5.2.2.1 Method.

a. Conduct accuracy and dispersion tests as described in TOP 4-2-829 for direct fire weapons or as described in TOP/MTP 3-1-004 for indirect fire weapons.

b. Determine projectile functioning characteristics and a preliminary estimate of reliability by firing the projectile with each of its various fuze types (impact, time, and proximity) for a minimum of 10 rounds per fuze type at 21.1° C (70° F) and, unless otherwise specified, at -51.1° C (-60° F) and +62.8° C (+145° F). Fire in accordance with paragraph 5.1.1a above. Functional firings may be conducted simultaneously with the accuracy and dispersion tests and range firing tests.

c. For white phosphorous projectiles, fire live rounds or utilize the reliability test firings to determine screening and signal effects as follows:

(1) Record the size, time to cloud buildup, shape and duration of the smoke cloud using a high-speed framing camera (or an optical instrument with graduated reticles in both the horizontal and vertical planes) emplaced a known distance from the cloud formation. Determine the electro-optical (EO) aspects of the cloud in terms of how it will effect the various active and passive EO devices.

(2) Estimate the density of the smoke cloud by the extent to which it conceals the target (brightly painted panel that approximates the size of a large combat vehicle).

(3) Determine the adequacy of the smoke cloud as a screening or signal device by aerial observation and photography.

d. When applicable, conduct static fragmentation tests as described in TOP/MTP 4-2-813 and compute lethality using the procedures of TOP/MTP 3-2-608.

e. For toxic chemical projectiles, determine troop harassment or incapacitation effects in accordance with TOP/MTP 8-2-513.

5.2.2.2 Data Required. Record test data as indicated by each procedure referenced above.

5.2.3 Illuminating Projectiles.

5.2.3.1 Method.

a. Conduct range firing tests as described in TOP/MTP 3-1-004.

b. Determine the functioning characteristics and a preliminary estimate of the reliability of the projectile as follows:

(1) Conduct static tests in which the projectile is held in a fixture and the fuze statically initiated. For safety reasons use an inert illuminant unless the candlepower of the illuminant is to be measured.

(2) Conduct dynamic tests by firing a group of 10 rounds each at each of three temperature levels: -45.6° C (-60° F), 21.1° C (70° F), and 62.8° C (145° F). Vary the firing elevations and the ejection altitudes throughout the range of expected field use at each temperature level. Investigate any performance anomalies by additional firings at intermediate temperature levels as appropriate.

5.2.3.2 Data Required.

a. Record range firing data as described in TOP/MTP 3-1-004.

b. Record the following for each round fired:

(1) Area illuminated, utilizing high speed cameras and aerial observation.

(2) Time of fuze functioning to ejection of suspension assembly.

(3) Time of effective illumination.

(4) Time of ejection to impact of illuminant on ground.

(5) Approximate range from weapon to burst of projectile.

(6) Approximate height of burst.

(7) Evidence of component malfunction:

(a) Parachute and illuminant assembly not ejecting.

(b) Failure of suspension assembly.

(c) Separation of illuminant assembly from suspension.

(d) Interrupted burning of the illuminant composition.

(8) Air temperature and relative humidity at firing point and near burst point before and after each group.

c. Record candlepower of the illuminant when applicable.

5.2.4 Target Practice Projectiles.

5.2.4.1 Method.

a. Conduct accuracy and dispersion tests as described in TOP 4-2-829 for direct fire weapons or as described in TOP/MTP 3-1-004 for indirect fire weapons.

b. For spotting charge rounds, determine the size, shape, and duration of the smoke cloud as described in paragraph 5.2.2.1c.

c. Determine tracer effectiveness, if applicable, under various atmospheric conditions (temperature, humidity, etc.) by observations and recording tracer time.

5.2.4.2 Data Required. Record data on projectile performance and test conditions as indicated by the procedures referenced above.

5.2.5 Armor-Defeating Projectiles.

5.2.5.1 Method.

a. Conduct accuracy and dispersion tests as described in TOP 4-2-829.

b. Determine the armor penetration ability of kinetic energy projectiles against specified targets as described in the appropriate section of TOP 2-2-710. Use at 12 rounds to establish the ballistic limit unless ammunition availability or cost is a restricting factor.

c. Determine the static and dynamic penetration ability of HEAT projectiles as described in TOP 4-2-812.

d. Determine HEP projectile spalling effect on armor as described in TOP 2-2-710. Determine blast overpressures as described in TOP/MTP 4-2-822.

5.2.5.2 Data Required. Record data on item performance and test conditions as indicated by the procedures referenced above.

6. DATA REDUCTION AND PRESENTATION.

a. Assemble, reduce, and summarize raw data in accordance with the requirements stated in each referenced TOP. Processing will include, but not be limited to, the following elements:

(1) Identification data for each test specimen, each test facility, and each measurement system.

(2) Complete data on the results of the firing of each test round.

(3) Comprehensive description of test conditions.

(4) Photographs for permanent documentation of significant test results and procedures.

b. Organize the test data into appropriate tables and graphs. Compute the mean and standard deviation of all numerical values for each parameter measured, and determine the effect of environmental factors. Compare performance data with the requirements and evaluate narratively in a comprehensive test report.

Recommended changes to this publication should be forwarded to Commander, U. S. Army Test and Evaluation Command, ATTN: DRSTE-AD-M, Aberdeen Proving Ground, MD 21005. Technical information may be obtained from the preparing activity: Commander, US Army Aberdeen Proving Ground, ATTN: STEAP-MT-M, Aberdeen Proving Ground, MD 21005. Additional copies are available from the Defense Documentation Center, Cameron Station, Alexandria, VA 22314. This document is identified by the accession number (AD No.) printed on the first page.

APPENDIX A
CHECKLIST GUIDE FOR PROJECTILE TESTS

ITEM	YES	NO	NA
1. All operating personnel briefed on test requirements, special procedures, hazards, and any unusual aspects of test.			
2. Gun tube wear within test requirements.			
3. Physical dimensions of projectile measured and recorded.			
4. Ammunition components inspected, assembled, available, and identified.			
5. All required instrumentation calibrated, properly installed, and operational.			
6. Wind conditions suitable for test firing.			
7. Weapon lay established.			
8. Safety requirements accomplished (SOP checklist completed and SOP posted*).			
9. Required data recorded.			

*SOP 385-67 at APG.

APPENDIX B
INERT FILLERS FOR HE PROJECTILES

1. APPLICATION. The following information is for guidance in the selection of inert filler compositions for projectiles used in tests of ammunition and weapons. It applies to all testing that requires the use of ammunition which, although not explosively loaded, must have some or all of the physical characteristics (i.e., weight, center of gravity, moment of inertia) of the production item. These characteristics may be simulated in part or totally by loading the projectiles with the different compositions described below. Military specifications and local operating procedures cover the processing techniques associated with each inert filler composition and the exact parts by weight of the nominal combination of constituents.

2. METHOD OF SELECTION. In selecting which type of filler composition to use for a particular test, study the degree of simulation necessary and other limitations associated with the inert filler compositions to assure that projectiles cast with a particular type of filler will meet the requirements of the test. Consider the environmental and economic factors associated with each type of filler. For background information review the following reports:

a. Hughes, T. G., Special Study of Test Method: Inert Filler for Artillery Projectiles (TECOM Project 9-4-0008-28), US Army Aberdeen Proving Ground, Report DPS-1992, April 1966.

b. Kinnard, George W., Methodology Investigation - Projectile Inert Filler Study (TECOM Project 9-CO-014-000-001), US Army Jefferson Proving Ground, Report MTD-1-5-75, June 1975.

c. Poughkeepsie, Frank B., Methodology Investigation Proposal, Improvement of Inert-Loading Capability (TECOM Project 7-CO-PB6-AP1-012), US Army Aberdeen Proving Ground, Report APG-MT-4836, July 1976.

2.1 Inert Filler Compositions Covered by Military Specification. The following types of materials, generally used by US Army ammunition plants, are described in MIL-I-60350 (MU). 2/ They are intended to be used as inert fillers in place of explosives in artillery projectiles as well as in other standard items of ammunition, and are selected based on the explosive load to be simulated.

Type	Criteria for Selection
Type I - Mixture of calcined gypsum, perlite, and water.	Simulates such high explosives as Composition B and 80/20 tritonal.

2/ MIL-I-60350(MU), Inert Fillers for Use in Ammunition, 30 October 1965.

Type	Criteria for Selection
Type II - Mixture of the glyceride of 12 hydroxy stearic acid, rosin, and dead-burned gypsum with or without ferric oxide.	Simulates such high explosives as TNT, Composition B, 52/48 picratol, 75/25 cyclotol, 80/20 tritonal, HBX-1, HBX-3, and HBX-6.
Type III - Mixture of aluminum ammonium sulfate, cellulose or barium sulfate, copper sulfate, and a corrosion inhibitor.	Simulates explosives having a specific gravity from 1.5 to 1.95. (Type III is compatible with TNT, RDX, and HMX.)

2.2 Inert Fillers Used by Proving Grounds. Since the proving grounds may not have inert-loading facilities that are adaptable to the filler types described in 2.1 above, they use the following types of materials as inert fillers in place of explosives for mortar, tank, and artillery projectiles.

Type	Criteria for Selection
Sand and Steel Punchings - A combination of sand described as Sand, Blast, NC Barkley Dry 18 Mesh Grade Number One and Punchings, Steel, size various ranging from 1.6- to 6.4-mm thick (1/16- to 1/4-in.) to 25.4 mm (1 inch) in diameter, clear, with slight coat of oil.	Use as a projectile filler for weapon tests requiring simulation of interior ballistic factors only. Use for tests involving measurement of maximum chamber pressure and kinetic energy impulses or recoil momentum on recoil mechanisms and carriages. Provides an economical and quick loading operation for projectiles when centers of gravity, moments of inertia, and other factors for simulating payloads are not of major concern in the test. Do not use sand and steel filler in projectiles for any testing in which exterior ballistic characteristics or certain interior ballistic factors are of concern; i.e., in long-term tests involving large numbers of rounds. Use of this filler type for such tests could lead to abnormal or uneven wear of gun tubes due to filler shift.
Low Temperature Wax-Base Filler - A mixture of paraffin wax, barium sulfate, and linseed oil.	Use as an inert filler for projectiles when testing at temperatures from -56.7° to +43.3° C (-70° to +110° F).

Type	Criteria for Selection
High Temperature Wax-Base Filler - A mixture of microcrystalline wax, barium sulfate, and linseed oil.	Use as an inert filler for projectiles when testing at temperatures from +43.3° to +71.1° C (+110° to +160° F).
Polyurethane Filler - A mixture of a prepolymer and resin-catalyst fractions.	Use as an inert filler with unlimited application. From an economic standpoint, it is more advantageous to use this filler for projectiles up to 155 mm in size rather than the wax-base filler. In addition, the processing time for loading all calibers of projectiles is greatly reduced with the polyurethane filler since it involves a one-pour operation as compared to two or three pours for the wax filler and requires a short curing time from time of pour until ready for firing (approximately 1 hour) as compared to several hours for the wax-base filler.

SUPPLEMENTARY

INFORMATION

AD-A068945

U. S. ARMY TEST AND EVALUATION COMMAND
Aberdeen Proving Ground, Maryland 21005

TOP 4-2-501
AD A068945
CHANGE 1

22 October 1979

PROJECTILES

TOP 4-2-501, 1 April 1979, is changed as follows:

1. Remove pages and insert new pages as indicated below:

Remove pages--	Insert pages--
5 and 6	5 and 6

2. A vertical line in the margin indicates the changed portion of the revised page.

3. Attach this sheet to the front of the reference copy for information.

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rifling. This lack of a clean impression is called "shearing" and is normal for a worn weapon. A recovered rotating band that is smooth, with no impression, may indicate that the weapon life has been exceeded or that the band design is inadequate, depending upon the life requirements of the system.)

(4) Evidence of filler leakage around joints of multipiece projectiles or movement of components with respect to one another.

(5) Rifling marks around the entire circumference of the recovered projectile body for evidence of upsetting; i.e., failure of cylindrical body in radial expansion caused by axial compression.

f. Certain projectiles such as high velocity, kinetic engergy, armor piercing projectiles, may not lend themselves to recovery as described in TOP 4-2-809. In these cases, the evaluation of strength of design must rely on data obtained from cameras, flash radiography, and radar. In the case of saboted, high velocity projectiles, it is often possible to recover parasitic hardware by thoroughly searching large areas forward of the weapon. Recovery of such parasitic hardware is often of extreme value in diagnosing the causes of metal parts failure during launch.

5.1.2 Data Required.

a. Projectile identification.

b. Complete round component identification.

c. Propelling charge weight.

d. Projectile physical measurements before and after firing as described in TOP/MTP 4-2-800.

e. Weapon identification.

f. Recovery method.

g. Firing elevation.

h. Firing data as specified in 5.1.1b above.

i. Results of examinations specified in 5.1.1e.

j. Meteorological data.

5.2 Terminal Effects. Determine projectile terminal effects using the procedures and subtests described below as applicable to the projectile being tested.

5.2.1 High Explosive Projectiles.

5.2.1.1 Method.

a. Conduct accuracy and dispersion tests as described in TOP 4-2-829 for direct fire weapons or as described in TOP/MTP 3-1-004 for indirect fire weapons.

b. Conduct static fragmentation tests as described in TOP/MTP 4-2-813.

c. Compute projectile lethality from the data collected in a and b above using the procedures of TOP/MTP 3-2-608.

d. Determine projectile functioning characteristics and a preliminary estimate of reliability by firing the projectile with each of its various fuze types (impact, time, and proximity) for a minimum of 10 rounds per fuze type at 21.1° C (70° F) and, unless otherwise specified, at -51.1° C (-60° F) and +62.8° C (+145° F). Fire in accordance with paragraph 5.2.1.1a above. Functional firings may be conducted simultaneously with the accuracy and dispersion tests and range firing tests.

e. Determine order of functioning using the criteria of TOP/MTP 4-1-003.

5.2.1.2 Data Required. Record test data as indicated by the specific procedures above.

5.2.2 Chemical Projectiles.

5.2.2.1 Method.

a. Conduct accuracy and dispersion tests as described in TOP 4-2-829 for direct fire weapons or as described in TOP/MTP 3-1-004 for indirect fire weapons.

b. Determine projectile functioning characteristics and a preliminary estimate of reliability by firing the projectile with each of its various fuze types (impact, time, and proximity) for a minimum of 10 rounds per fuze type at 21.1° C (70° F) and, unless otherwise specified, at -51.1° C (-60° F) and +62.8° C (+145° F). Fire in accordance with paragraph 5.2.1.1a above. Functional firings may be conducted simultaneously with the accuracy and dispersion tests and range firing tests.

c. For white phosphorous projectiles, fire live rounds or utilize the reliability test firings to determine screening and signal effects as follows: